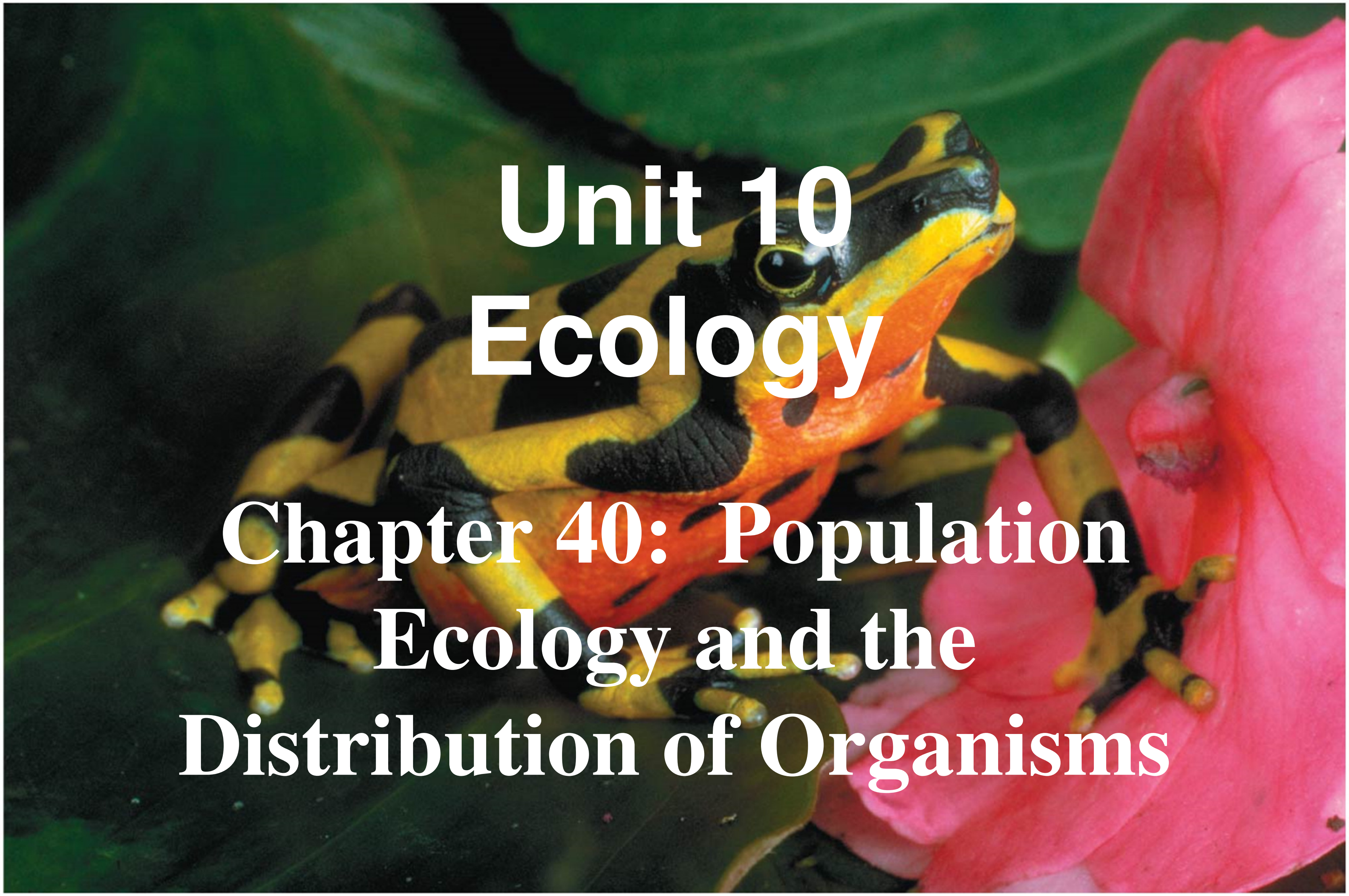


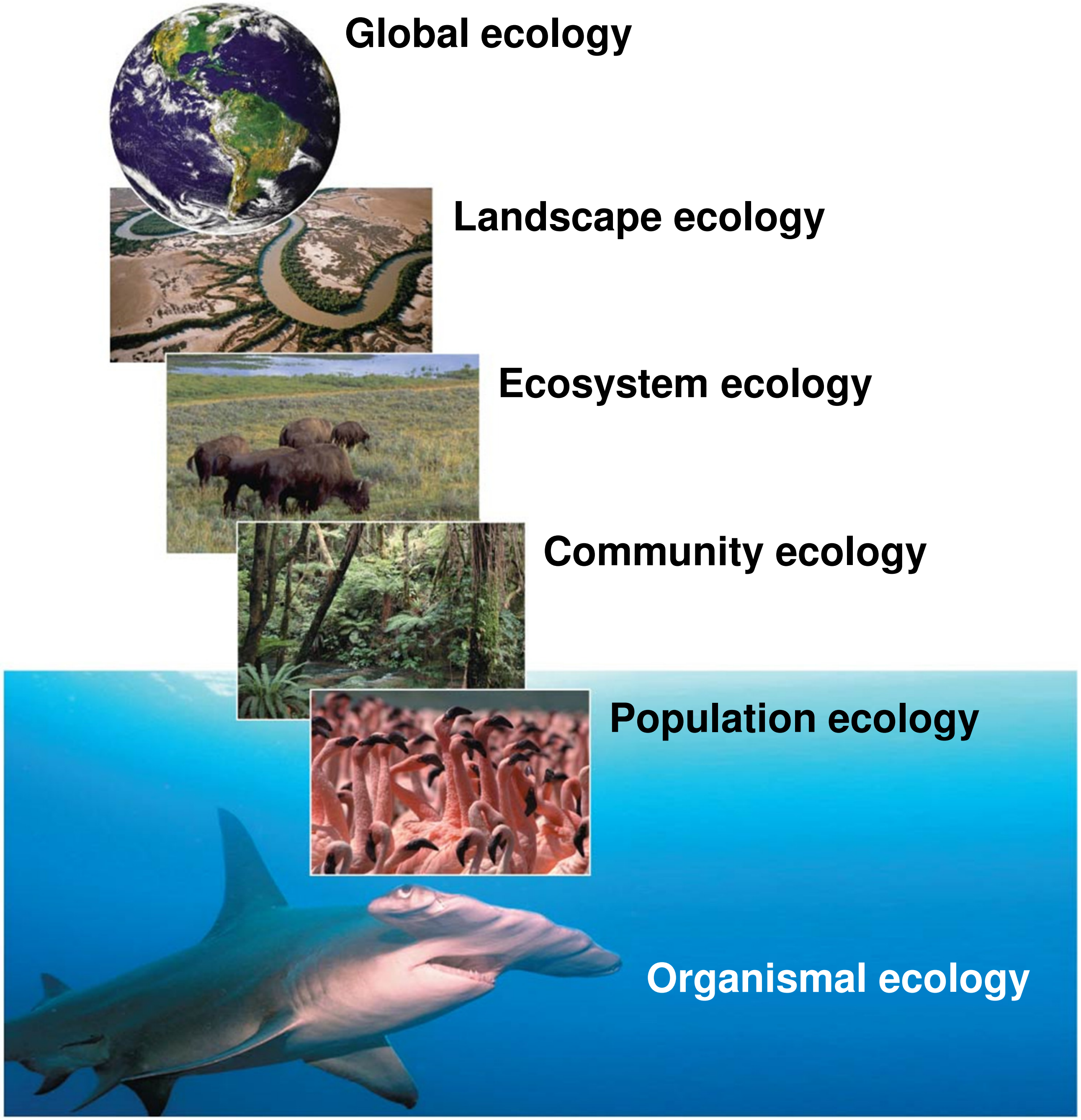
Unit 10
Ecology

Chapter 40: Population Ecology and the Distribution of Organisms

Overview: Discovering Ecology

- **Ecology** is the scientific study of the interactions between organisms and the environment
  - These interactions determine the distribution of organisms and their abundance

Figure 40.2



Global ecology
Landscape ecology
Ecosystem ecology
Community ecology
Population ecology
Organismal ecology

- **Global ecology** is concerned with the biosphere, or global ecosystem
  - The **biosphere** is the sum of all the planet's ecosystems
  - Global ecology examines the influence of energy and materials on organisms across the biosphere
- **Landscape ecology** focuses on the exchanges of energy, materials, and organisms across multiple ecosystems
  - A **landscape** (or seascape) is a mosaic of connected ecosystems

- **Ecosystem ecology** emphasizes energy flow and chemical cycling among the various biotic and abiotic components
  - An **ecosystem** is the community of organisms in an area and the physical factors with which they interact
- **Community ecology** deals with the whole array of interacting species in a community
  - A **community** is a group of populations of different species in an area

- **Population ecology** focuses on factors affecting population size over time
  - A **population** is a group of individuals of the same species living in an area
- **Organismal ecology** studies how an organism's structure, physiology, and (for animals) behavior meet environmental challenges
  - Organismal ecology includes physiological, evolutionary, and behavioral ecology

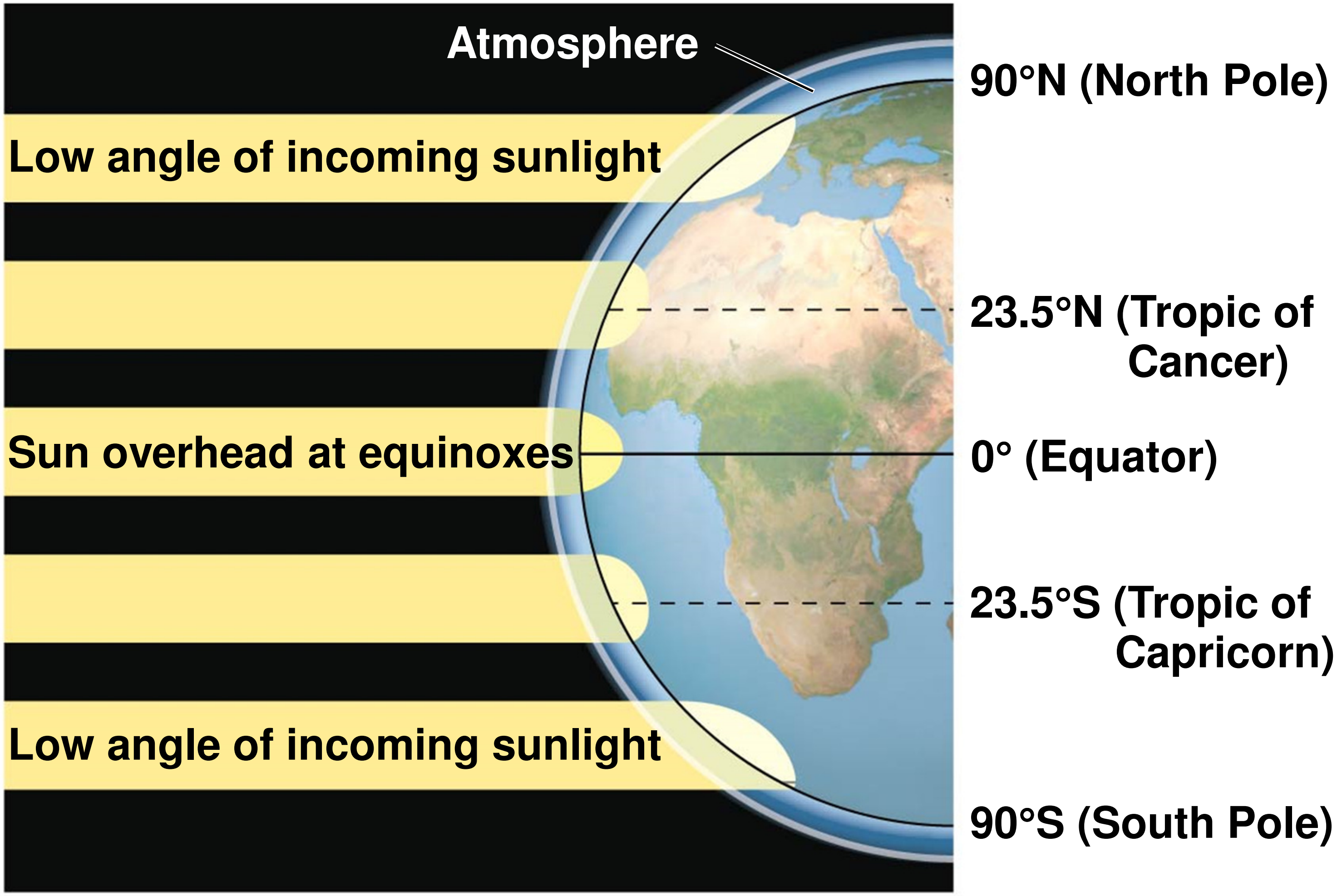
Concept 40.1: Earth's climate influences the structure and distribution of terrestrial biomes

- The long-term prevailing weather conditions in an area constitute its **climate**
  - Four major abiotic components of climate are
    - Temperature
    - Precipitation
    - Sunlight
    - Wind
- **Abiotic** factors are the nonliving chemical and physical attributes of the environment
- **Biotic** factors are the other organisms that make up the living component of the environment

Global Climate Patterns

- Global climate patterns are determined largely by solar energy and the planet's movement in space
  - The warming effect of the sun causes temperature variations
  - Drives evaporation and the circulation of air and water
- Causes latitudinal variations in climate
  - Sunlight strikes the tropics most directly
  - At higher latitudes, where sunlight strikes Earth at an oblique angle, light is more diffuse

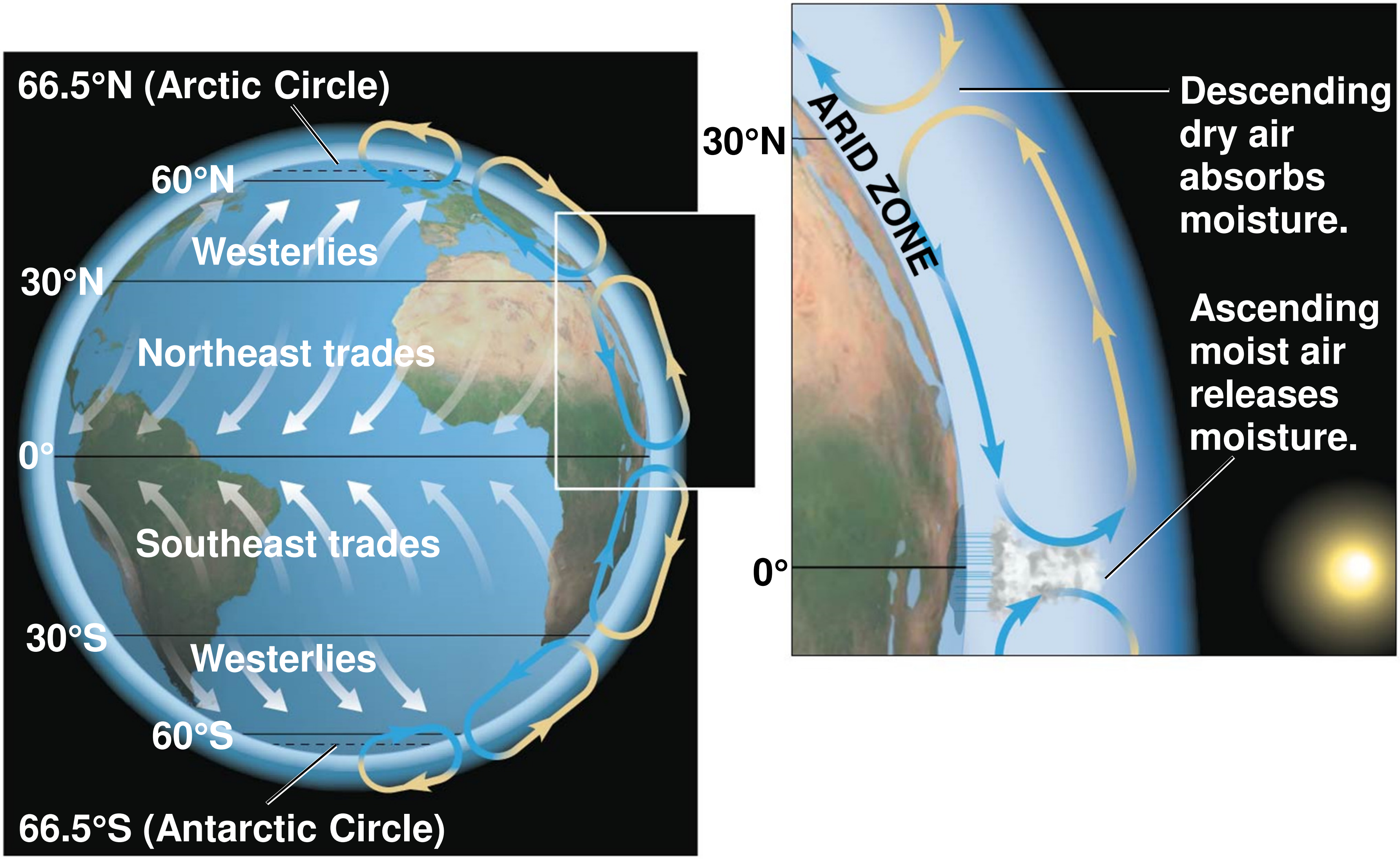
Figure 40.3a



Latitudinal variation in sunlight intensity

- Warm, wet air rising near the equator creates precipitation in the tropics
- Dry air descending causes desert conditions
  - This pattern of precipitation and drying is repeated at different latitudes
- Variation in the speed of Earth's rotation at different latitudes results in the major wind patterns
  - Trade winds blow east to west in the tropics
  - Westerlies blow west to east in temperate zones

Figure 40.3b



Global air circulation and precipitation patterns

Regional Effects on Climate

- Climate is affected by
  - Seasonality
    - Seasonal variations in light and temperature
    - Caused by the tilt of Earth's axis of rotation and its annual passage around the sun (in higher latitudes)
  - Large bodies of water
    - Moderate climate of nearby land due to water's high specific heat capacity
  - Mountains
    - Influence air flow over land
      - Moisture on windward side
      - Dry air on leeward side (deserts)

Figure 40.4

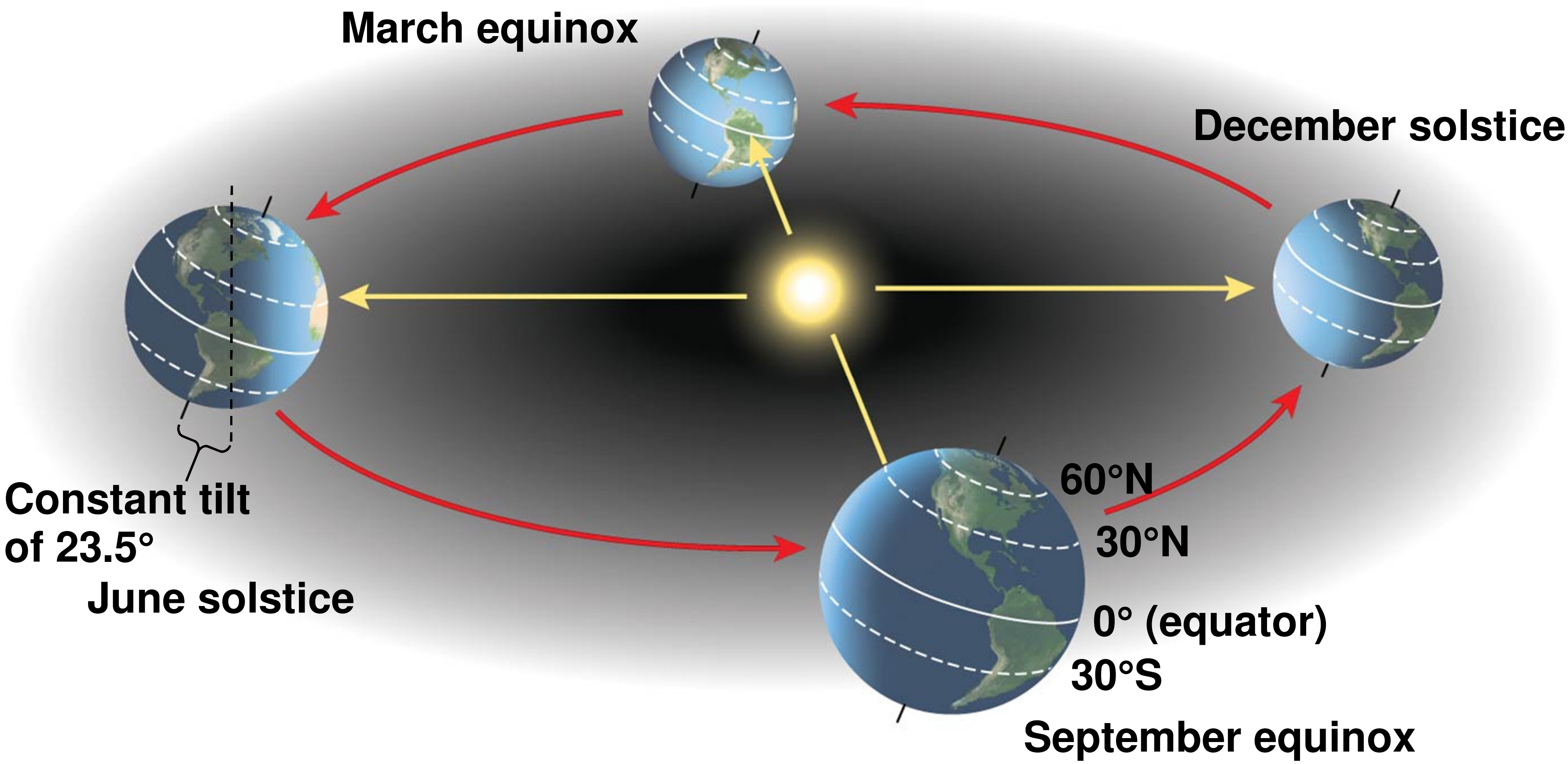
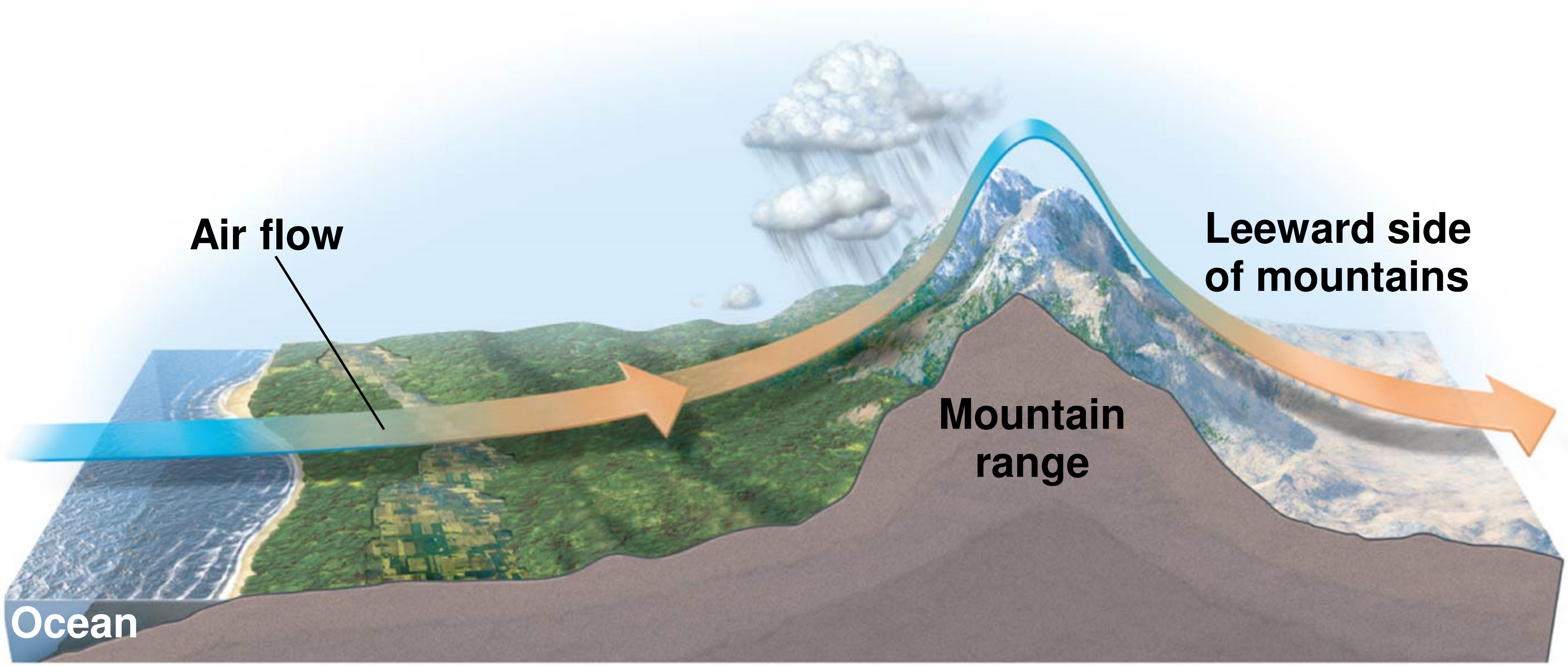

March equinox
December solstice
Constant tilt of 23.5°
June solstice
60°N
30°N
0° (equator)
30°S
September equinox

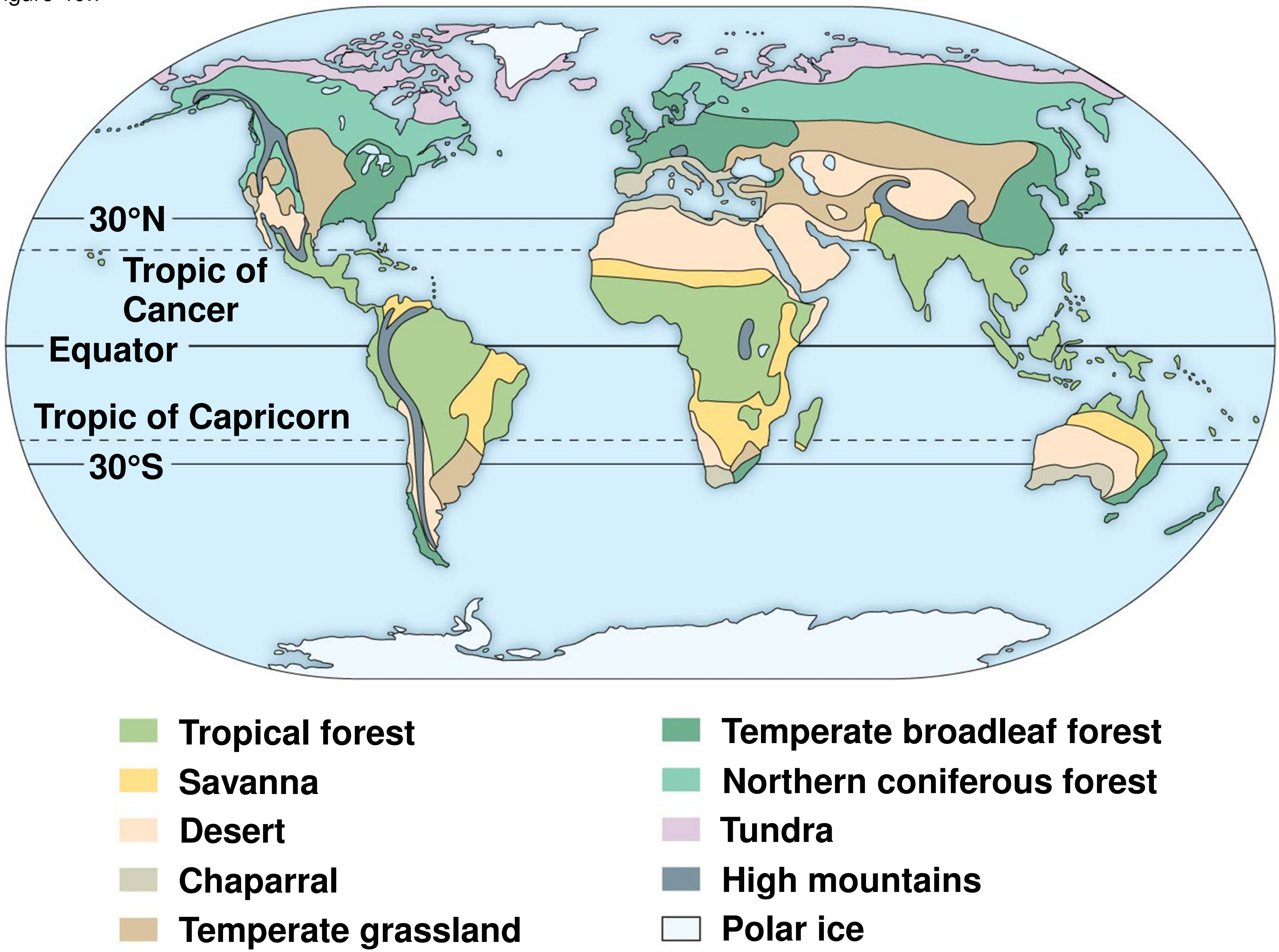
Figure 40.6



Climate and Terrestrial Biomes

- **Biomes** are major life zones characterized by
  - Vegetation type (terrestrial biomes)
  - Physical environment (aquatic biomes)
- Climate is very important in determining why terrestrial biomes are found in certain areas
- Natural and human-caused disturbances alter the distribution of biomes
  - A **disturbance** is an event that changes a community by removing organisms and altering resource availability

Figure 40.7


30°N
Tropic of Cancer
Equator
Tropic of Capricorn
30°S
Tropical forest
Savanna
Desert
Chaparral
Temperate grassland
Temperate broadleaf forest
Northern coniferous forest
Tundra
High mountains
Polar ice

General Features of Terrestrial Biomes

- Terrestrial biomes are often named for major physical or climatic factors and for vegetation
- Terrestrial biomes usually grade into each other, without sharp boundaries
  - The area of intergradation is called an **ecotone**
- Terrestrial biomes can be characterized by distribution, precipitation, temperature, plants, and animals

- Tropical forests occur in equatorial and subequatorial regions
  - Temperature is high year-round (25–29°C) with little seasonal variation
- In **tropical rain forests**, rainfall is relatively constant
- In **tropical dry forests** precipitation is highly seasonal
- Rapid human population growth is now destroying many tropical forests
  - Agriculture
  - Development

- **Savanna** occurs in equatorial and subequatorial regions
  - Precipitation is seasonal
  - Temperature averages 24–29°C but is more seasonally variable than in the tropics
  - Fires are common in dry season

- **Deserts** occur in bands near 30° north and south of the equator and in the interior of continents
  - Precipitation is low and highly variable, generally less than 30 cm per year
  - Deserts may be hot (>50°C) or cold (–30°C) with seasonal and daily temperature variation
  - Urbanization and conversion to irrigated agriculture have reduced the natural biodiversity of some deserts

- **Chaparral** occurs in midlatitude coastal regions on several continents
  - Precipitation is highly seasonal with rainy winters and dry summers
  - Summer is hot (30°C)
  - Fall, winter, and spring are cool (10–12°C)
  - Fires and drought

- **Temperate grasslands** occur at midlatitudes, often in the interior of continents
  - Precipitation is highly seasonal
  - Winters are cold (often below –10°C) and dry
  - Summers are hot (often near 30°C) and wet
  - Most grasslands have been converted to farmland

- **Temperate broadleaf forest** is found at midlatitudes in the Northern Hemisphere, with smaller areas in Chile, South Africa, Australia, and New Zealand
  - Significant amounts of precipitation fall during all seasons as rain or snow
  - Winters average 0°C
  - Summers are hot and humid (near 35°C)
  - Heavily settled globally
    - Logging and land clearing

- **Northern coniferous forest**, or taiga, spans northern North America and Eurasia and is the largest terrestrial biome on Earth
  - Precipitation ranges from 30–70 cm
  - Winters are cold
  - Summers may be hot (e.g., Siberia ranges from –50°C to 20°C)
  - Some forests are being logged at an alarming rate

- **Tundra** covers expansive areas of the Arctic
- Alpine tundra exists on high mountaintops at all latitudes
  - Precipitation is low in arctic tundra and higher in alpine tundra
  - Winters are cold (below –30°C)
  - Summers are relatively cool (less than 10°C)
  - Settlement is sparse, but tundra has become the focus of oil and mineral extraction

Concept 40.2: Aquatic biomes are diverse and dynamic systems that cover most of Earth

- Aquatic biomes account for the largest part of the biosphere in terms of area
  - Show less latitudinal variation than terrestrial biomes
- Marine biomes have salt concentrations of about 3%
  - The largest marine biome is made of oceans, which cover about 75% of Earth's surface and have an enormous impact on the biosphere
- Freshwater biomes have salt concentrations of less than 0.1%
  - Freshwater biomes are closely linked to soils and the biotic components of the surrounding terrestrial biome

- Aquatic biomes can be characterized by their
  - Physical and chemical environment
  - Geological features
  - Photosynthetic organisms
  - Heterotrophs

- Wetlands and estuaries are among the most productive habitats on Earth
  - **Wetlands** are inundated by water at least sometimes and support plants adapted to water-saturated soil
  - An **estuary** is a transition area between river and sea
    - Salinity varies with the rise and fall of the tides

- High organic production and decomposition in these biomes result in low levels of dissolved oxygen
- Filling, dredging, and upstream pollution have disrupted and destroyed many of these ecosystems

- Lakes vary in size from small ponds to very large lakes
- Temperate lakes may have a seasonal thermocline
- Tropical lowland lakes have a year-round thermocline
- **Oligotrophic lakes** are nutrient-poor and generally oxygen-rich
- **Eutrophic lakes** are nutrient-rich and often depleted of oxygen

- Rooted and floating aquatic plants live in the shallow and well-lighted **littoral zone** close to shore
- Water is too deep in the **limnetic zone** to support rooted aquatic plants
  - Primary producers here are phytoplankton
- Human-induced nutrient enrichment can lead to algal blooms, oxygen depletion, and fish kills

- Streams and rivers have varying environmental conditions from headwater to mouth
  - Headwater streams are generally cold, clear, turbulent, swift, and oxygen-rich
    - Often narrow and rocky

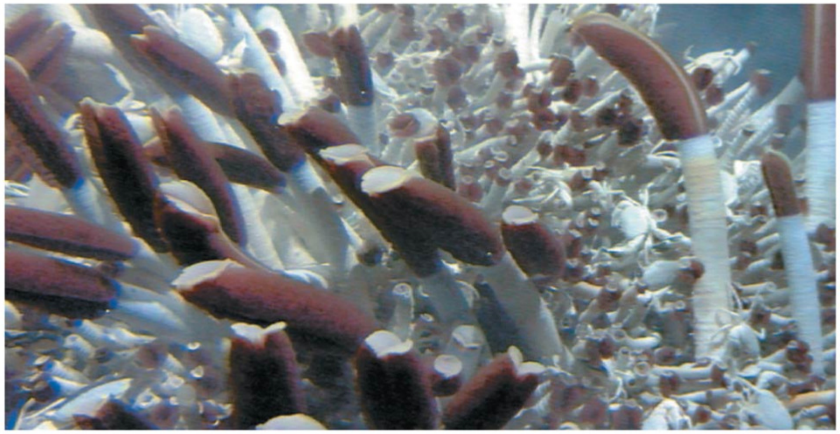
  - Downstream waters form rivers and are generally warmer and more turbid
    - Often wide and meandering and have silty bottoms
  - Salt and nutrients increase from headwaters to mouth
  - Oxygen content decreases from headwaters to mouth
- Pollution kills aquatic organisms
- Dams impair natural flow of stream and river ecosystems

- **Intertidal zones** are periodically submerged and exposed by the tides
  - Intertidal organisms are challenged by variations in temperature and salinity and by the mechanical forces of wave action
  - Oxygen and nutrient levels are high
  - Oil pollution has disrupted many intertidal areas

- **Coral reefs** are formed from the calcium carbonate skeletons of corals (cnidarians)
  - Corals require high oxygen concentrations and a solid substrate for attachment
  - A coral reef progresses from a fringing reef to a barrier reef to a coral atoll
  - Coral collection, overfishing, global warming, and pollution all contribute reduction in coral populations

- The **oceanic pelagic zone** is constantly mixed by wind-driven oceanic currents
  - Oxygen levels are high
  - Turnover in temperate oceans renews nutrients in the photic zones
  - This biome covers approximately 70% of Earth's surface
  - Overfishing has depleted fish stocks
  - Humans have polluted oceans with dumping of waste

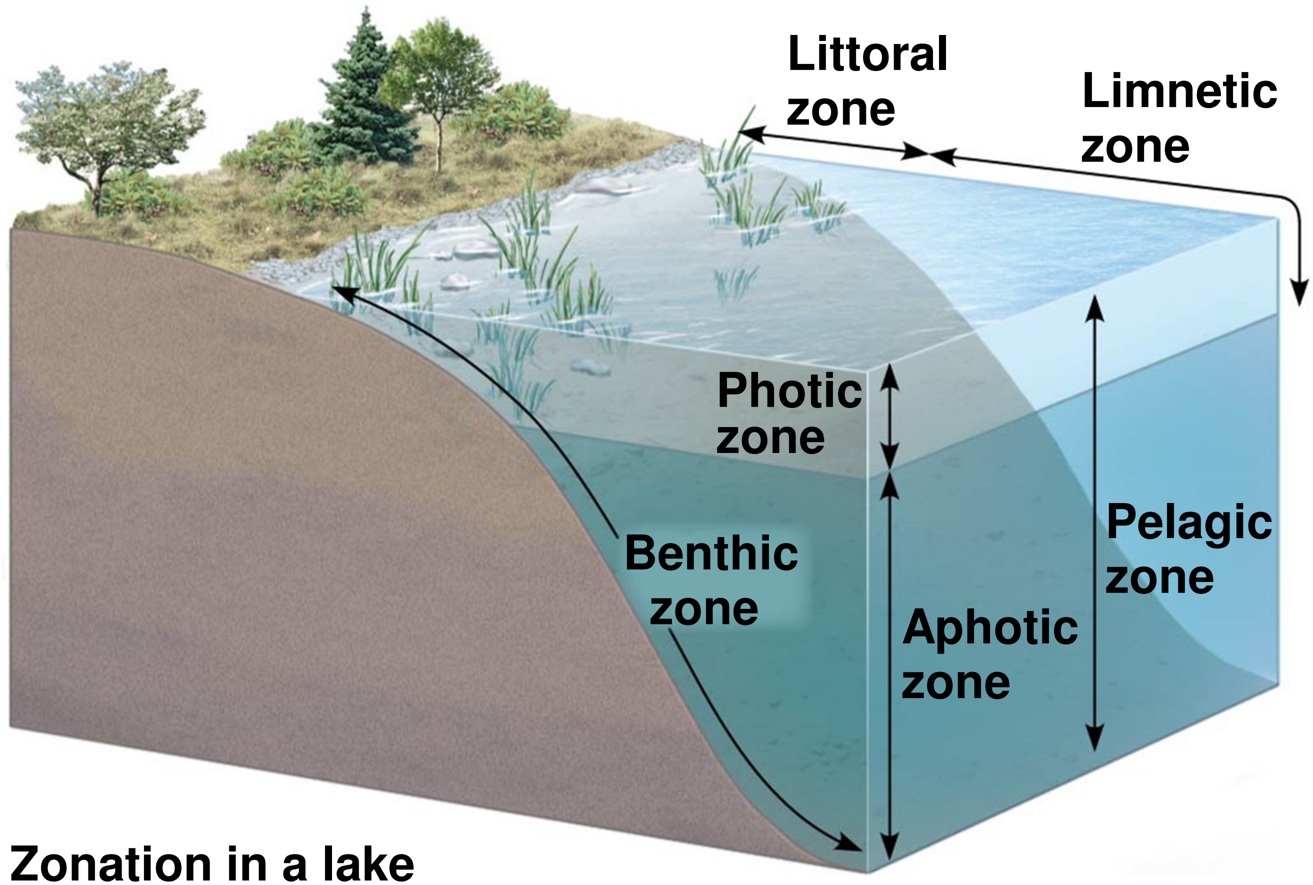
- The **marine benthic zone** consists of the seafloor
  - Organisms in the very deep benthic (abyssal) zone are adapted to continuous cold and high water pressure
  - In dark, hot environments near **deep-sea hydrothermal vents** of volcanic origin, the food producers are chemoautotrophic prokaryotes
  - Overfishing and dumping of organic waste have depleted fish populations



Zonation in Aquatic Biomes

- Many aquatic biomes are stratified into zones or layers defined by light penetration, temperature, and depth
- The upper **photic zone** has sufficient light for photosynthesis
- The lower **aphotic zone** receives little light
- The photic and aphotic zones make up the **pelagic zone**
- The organic and inorganic sediment at the bottom of all aquatic zones is called the **benthic zone**
- The communities of organisms in the benthic zone are collectively called the **benthos**

Figure 40.11



Zonation in a lake

- In oceans and most lakes, a temperature boundary called the **thermocline** separates the warm upper layer from the cold deeper water
- Communities in aquatic biomes vary with depth, light penetration, distance from shore, and position in the pelagic or benthic zone
  - Most organisms occur in the relatively shallow photic zone
  - The aphotic zone in oceans is extensive but harbors little life

Concept 40.3: Interactions between organisms and the environment limit the distribution of species

- Ecologists ask questions about where species occur and why species occur where they do

Dispersal and Distribution

- **Dispersal** is the movement of individuals away from centers of high population density or from their area of origin
  - Contributes to the global distribution of organisms
- Transplants indicate if dispersal is a key factor limiting species distributions
  - Transplants include organisms that are intentionally or accidentally relocated from their original distribution
- If a transplant is successful, it indicates that the species' potential range is larger than its actual range
- Species transplants can disrupt the communities or ecosystems to which they have been introduced

Biotic Factors

- Biotic factors that affect the distribution of organisms may include
  - Predation
  - Herbivory
  - Mutualism
    - Presence or absence of pollinators
  - Parasitism and pathogens
  - Food resources
    - Competition

Abiotic Factors

- Abiotic factors affecting the distribution of organisms include
  - Temperature
    - Cells may rupture if they freeze
    - Proteins of most organisms denature at high temps
  - Water and oxygen
    - Organisms may dry out
  - Salinity
    - Osmoregulation
  - Sunlight
    - Photosynthesis
  - Rocks and soil
    - Physical structure, pH, mineral composition

Concept 40.4: Dynamic biological processes influence population density, dispersion, and demographics

- Population ecology explores how biotic and abiotic factors influence density, distribution, and size of populations
  - A population is a group of individuals of a single species living in the same general area
  - Populations are described by their boundaries and size

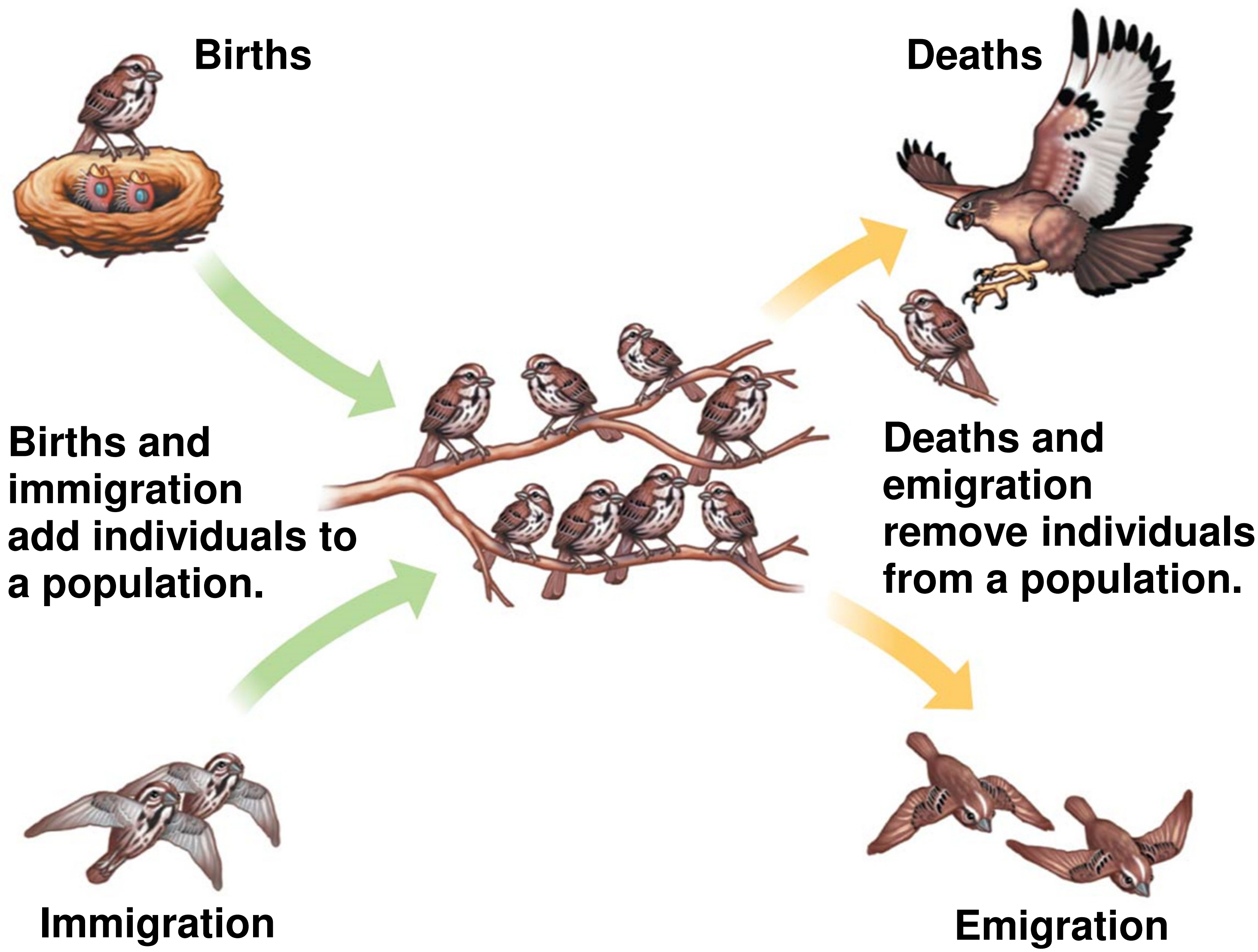
Density and Dispersion

- **Density** is the <u>number</u> of individuals per unit area or volume
- **Dispersion** is the <u>pattern of spacing</u> among individuals within the boundaries of the population

Density: A Dynamic Perspective

- Density is the result of an interplay between processes that add individuals to a population and those that remove individuals
- Additions occur through birth and **immigration**
  - Influx of new individuals from other areas
- Removal of individuals occurs through death and **emigration**
  - Movement of individuals out of a population

Figure 40.14


Births
Deaths
Births and immigration add individuals to a population.
Deaths and emigration remove individuals from a population.
Immigration
Emigration

Patterns of Dispersion

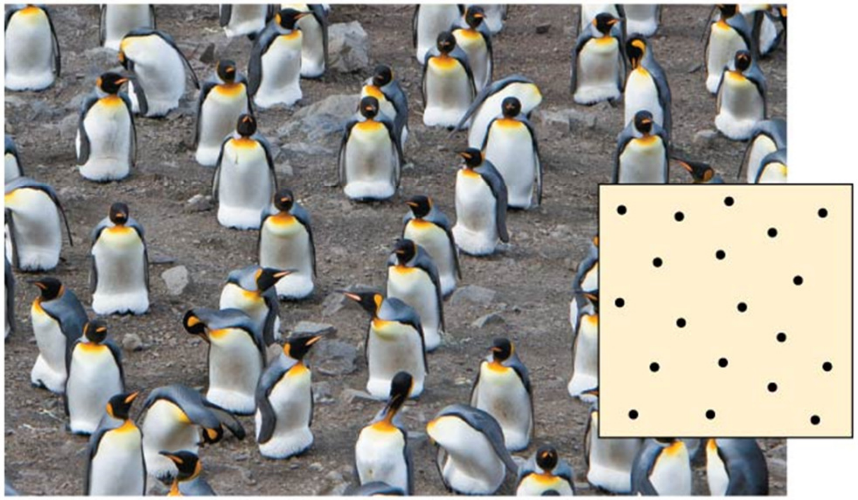
- Environmental and social factors influence the spacing of individuals in a population

- The most common pattern of dispersion is *clumped*
  - Individuals aggregate in patches
  - A clumped dispersion may be influenced by resource availability and behavior
    - May increase effectiveness of predation or defense

- A *uniform* dispersion is one in which individuals are evenly distributed
  - May result from direct interactions between individuals in the population
  - Ex: **Territoriality**
    - Defense of a bounded space against other individuals
- In a *random* dispersion, the position of each individual is independent of other individuals
  - Occurs in the absence of strong attractions or repulsions

Figure 40.15

(a) Clumped



(b) Uniform

(c) Random

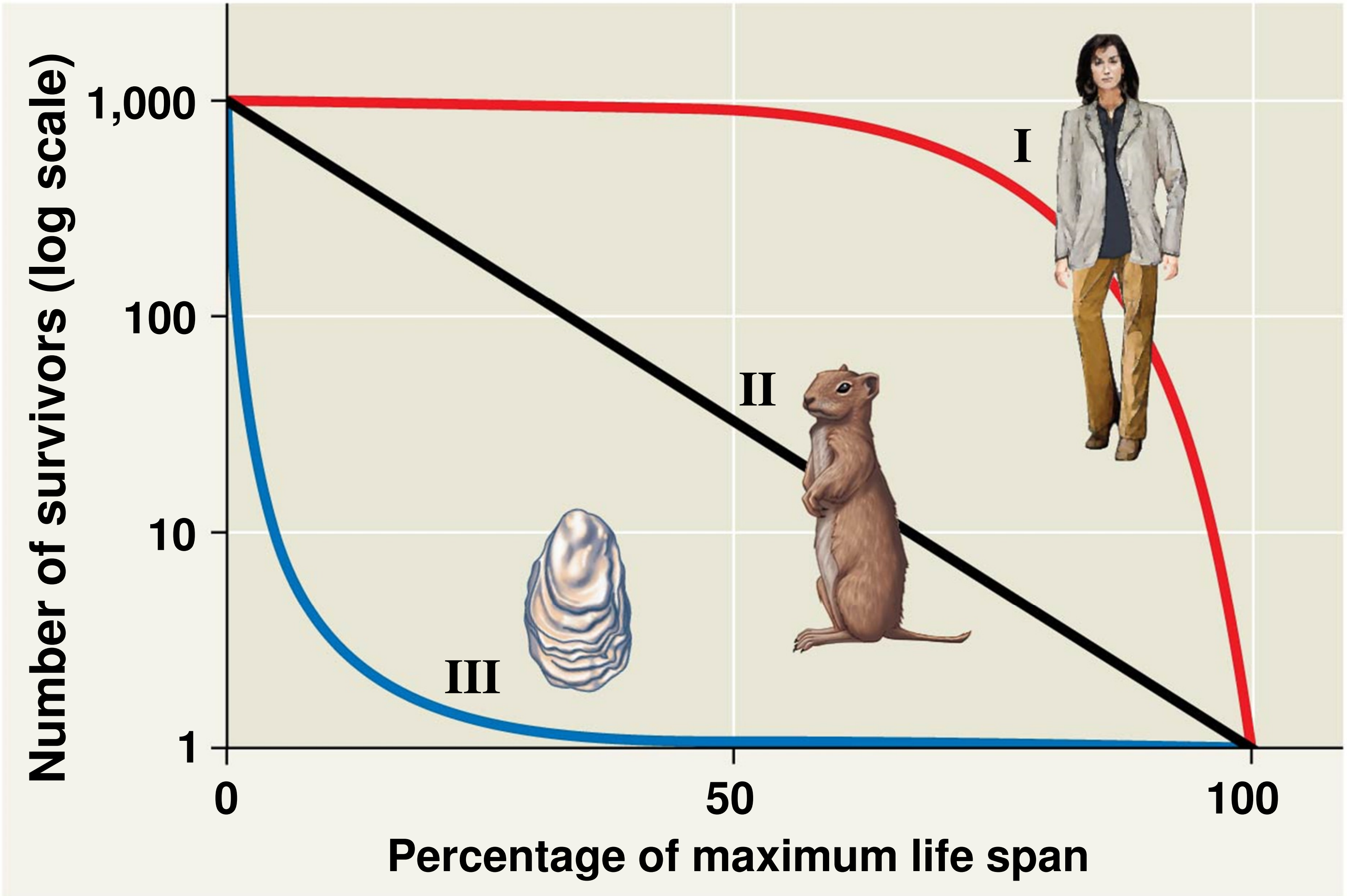
Demographics

- **Demography** is the study of the vital statistics of a population and how they change over time
- Death rates and birth rates are of particular interest to demographers

- A **life table** is an age-specific summary of the survival pattern of a population
  - It is best made by following the fate of a group of individuals of the same age from birth to death
    - Called a **cohort**
- A **survivorship curve** is a graphic way of representing the data in a life table
  - Plot the proportion or numbers of a cohort still alive at each age

- Survivorship curves can be classified into three general types
  - Type I: low death rates during early and middle life and an increase in death rates among older age groups
    - Large mammals, including humans
  - Type II: a constant death rate over the organism's life span
    - Rodents, invertebrates, lizards, annual plants
  - Type III: high death rates for the young and a lower death rate for survivors
    - Organisms that produce large numbers of offspring with little/no parent care (long-lived plants, fish, marine invertebrates)
- Many species are intermediate to these curves

Figure 40.16



Number of survivors (log scale)
1,000
100
10
1
0
50
100
Percentage of maximum life span
I
II
III

Reproductive Rates

- For species with sexual reproduction, demographers often concentrate on females in a population
- A **reproductive table**, or fertility schedule, is an age-specific summary of the reproductive rates in a population
- It describes the reproductive patterns of a population

Concept 40.5: The exponential and logistic models describe the growth of populations

- Unlimited growth occurs under ideal conditions
  - In nature, growth is limited by various factors
  - As population density increases, each individual has access to fewer resources
- Ecologists study growth in both idealized and realistic conditions

Per Capita Rate of Increase

- Change in population size can be defined by the equation

$$\text{Change in population size} = \text{Births} + \text{Immigrants entering population} - \text{Deaths} - \text{Emigrants leaving population}$$

- If immigration and emigration are ignored, a population's growth rate (per capita increase) equals birth rate minus death rate

- The population growth rate can be expressed mathematically as

$$\frac{\Delta N}{\Delta t} = B - D$$

- ΔN is the change in population size
- Δt is the time interval
- B is the number of births
- D is the number of deaths

- Births and deaths can be expressed as the average number of births and deaths per individual during the specified time interval
  - *b* is the annual per capita birth rate
  - *m* (for mortality) is the per capita death rate
  - *N* is population size

$$B = bN$$
$$D = mN$$

- The population growth equation can be revised

$$\frac{\Delta N}{\Delta t} = bN - mN$$

- The per capita rate of increase (*r*) is given by

$$r = b - m$$

- **Zero population growth (ZPG)** occurs when the birth rate equals the death rate ($r = 0$)

- Change in population size can now be written as

$$\frac{\Delta N}{\Delta t} = rN$$

- Instantaneous growth rate can be expressed as

$$\frac{dN}{dt} = r_{\text{inst}} N$$

where r_{inst} is the instantaneous per capita rate of increase

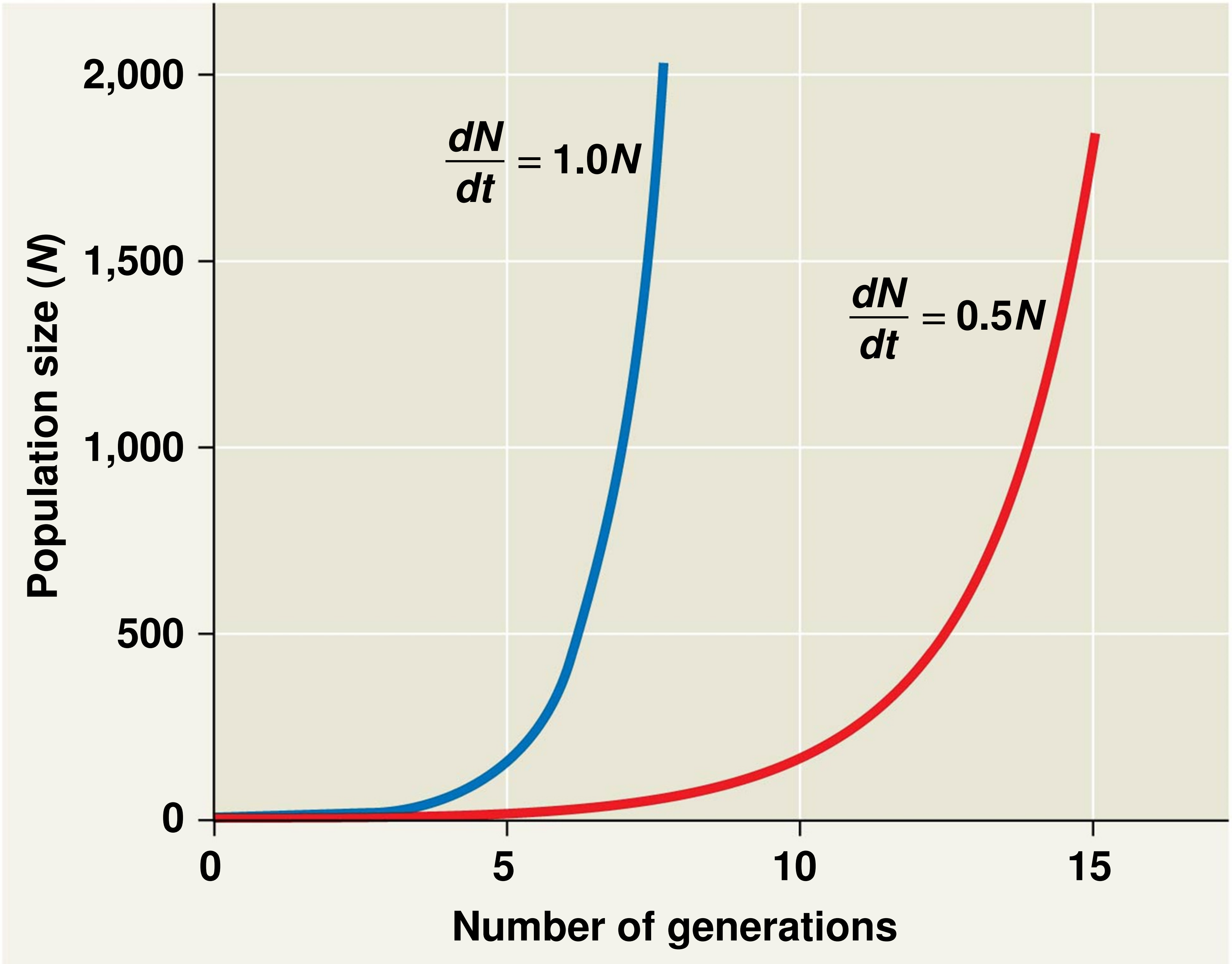
Exponential Growth

- **Exponential population growth** is population increase under idealized conditions
  - Under these conditions, the rate of increase is at its maximum, denoted as r_{max}
  - The equation of exponential population growth is

$$\frac{dN}{dt} = r_{\max} N$$

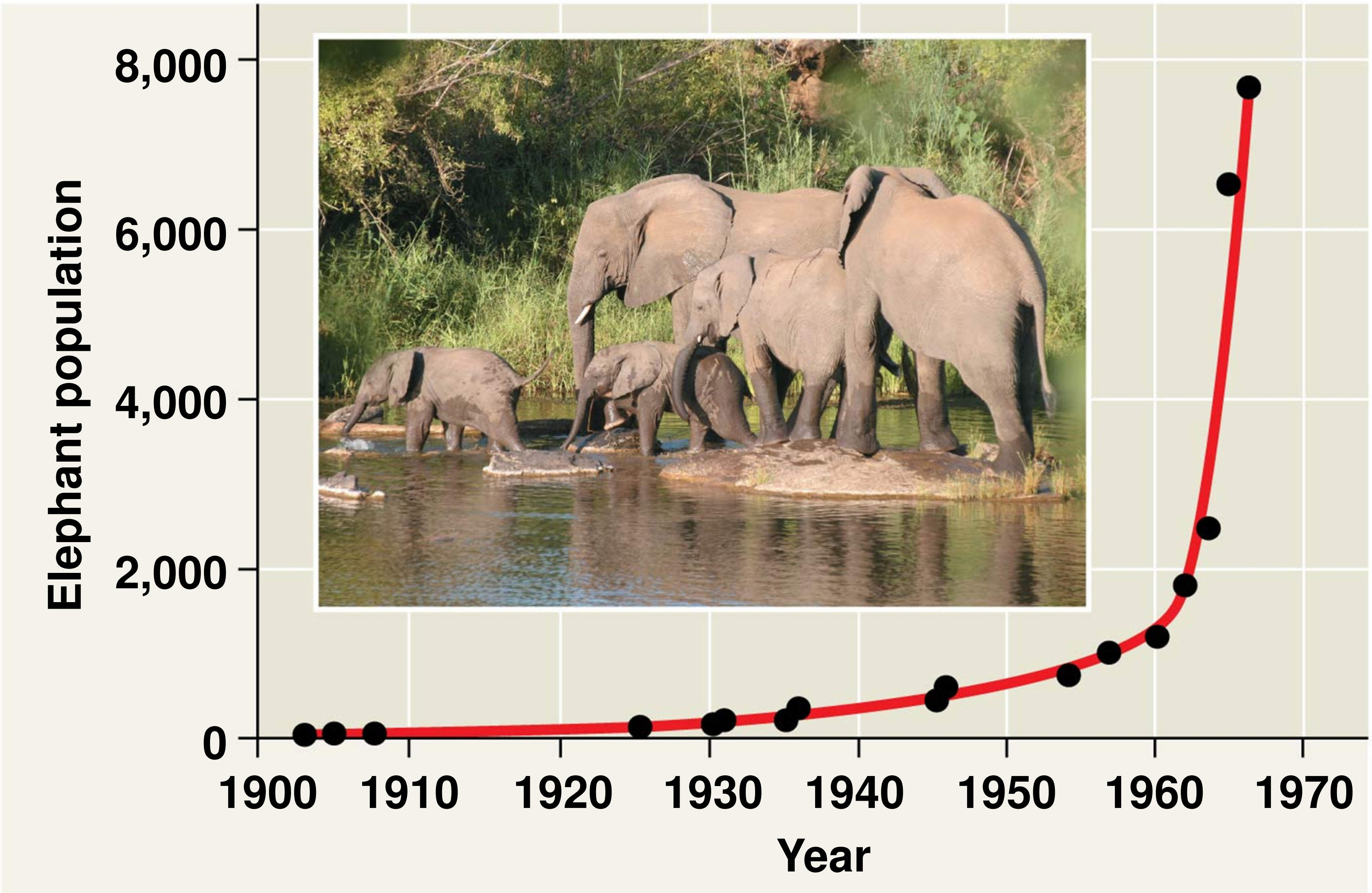
- Exponential population growth results in a J-shaped curve
  - Characterizes populations in new environments or rebounding populations

Figure 40.17



$\frac{dN}{dt} = 1.0N$
$\frac{dN}{dt} = 0.5N$
Population size (N)
2,000
1,500
1,000
500
0
0
5
10
15
Number of generations

Figure 40.18



Elephant population
8,000
6,000
4,000
2,000
0
1900
1910
1920
1930
1940
1950
1960
1970
Year

Carrying Capacity

- Exponential growth cannot be sustained for long in any population, as it assumes resources are unlimited
  - A more realistic population model limits growth by incorporating carrying capacity
- **Carrying capacity** (*K*) is the maximum population size the environment can support
  - Varies with the abundance of limiting resources

The Logistic Growth Model

- In the **logistic population growth** model, the per capita rate of increase declines as carrying capacity is reached
- The logistic model starts with the exponential model and adds an expression that reduces per capita rate of increase as *N* approaches *K*

$$\frac{dN}{dt} = r_{\max} N \frac{(K - N)}{K}$$

- The logistic model of population growth produces a sigmoid (S-shaped) curve

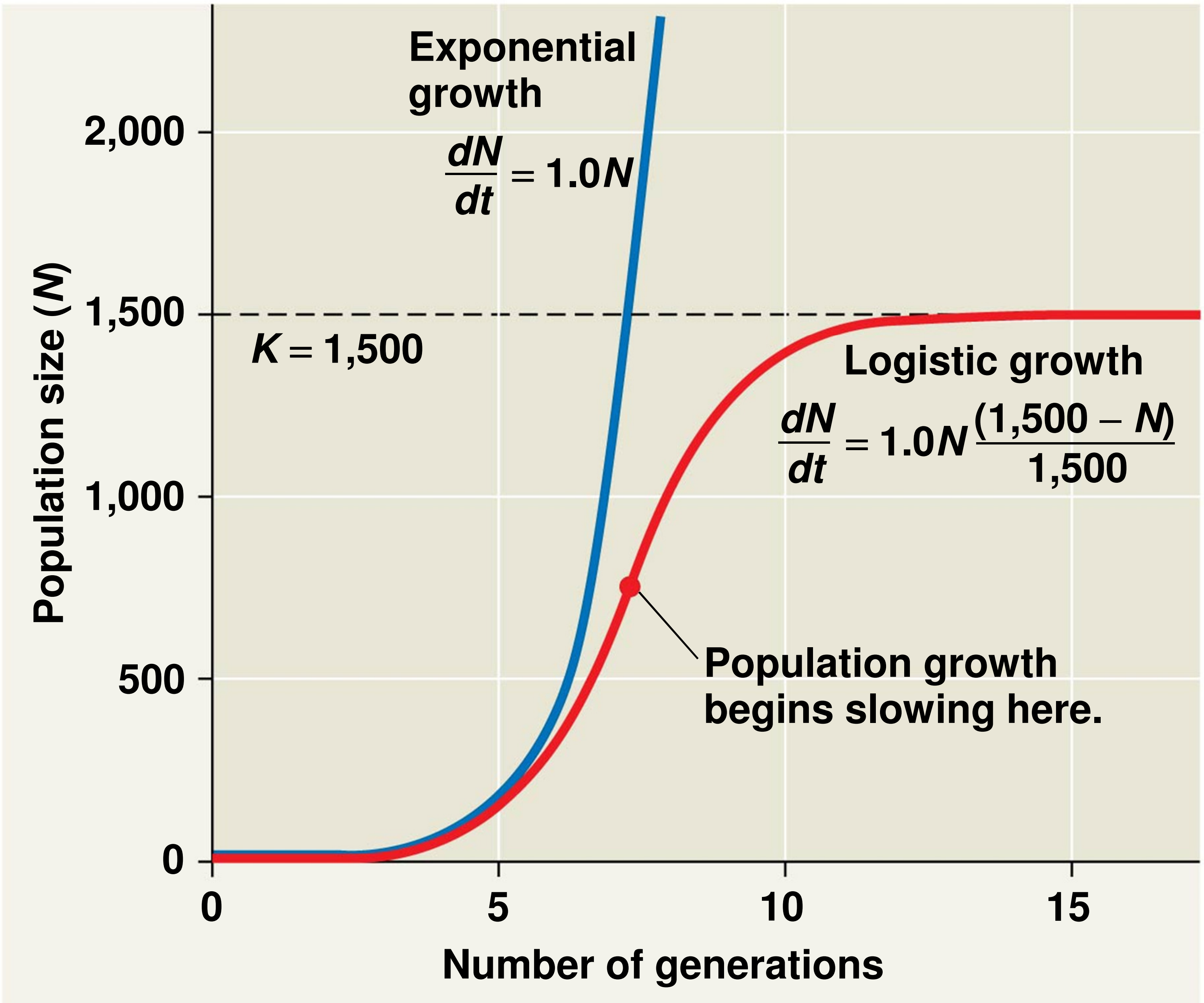
Table 40.2

Table 40.2 Logistic Growth of a Hypothetical Population ($K = 1{,}500$)

Population Size (N)	Maximum Rate of Increase (r_{max})	$\frac{K - N}{K}$	Per Capita Rate of Increase $r_{max}\frac{(K - N)}{K}$	Population Growth Rate* $r_{max}N\frac{(K - N)}{K}$
25	1.0	0.98	0.98	+ 25
100	1.0	0.93	0.93	+ 93
250	1.0	0.83	0.83	+ 208
500	1.0	0.67	0.67	+ 333
750	1.0	0.50	0.50	+ 375
1,000	1.0	0.33	0.33	+ 333
1,500	1.0	0.00	0.00	0

*Rounded to the nearest whole number.

Figure 40.19



Exponential growth
$\frac{dN}{dt} = 1.0N$
2,000
1,500
K = 1,500
1,000
500
0
Population size (N)
Logistic growth
$\frac{dN}{dt} = 1.0N\frac{(1{,}500 - N)}{1{,}500}$
Population growth begins slowing here.
0
5
10
15
Number of generations

Concept 40.6: Population dynamics are influenced strongly by life history traits and population density

- An organism's **life history** comprises the traits that affect its schedule of reproduction and survival
  - The age at which reproduction begins
  - How often the organism reproduces
  - How many offspring are produced during each reproductive cycle
    - Investment in parental care?

“Trade-offs” and Life Histories

- Organisms have finite resources, which may lead to trade-offs between survival and reproduction
- Selective pressures influence the trade-off between the number and size of offspring
  - Some plants produce a large number of small seeds, ensuring that at least some of them will grow and eventually reproduce
  - Other types of plants produce a moderate number of large seeds that provide a large store of energy that will help seedlings become established

Figure 40.21

Dandelions grow quickly and release a large number of tiny fruits.

The Brazil nut tree (above), produces a moderate number of large seeds in pods (left).

- ***K*-selection** selects for life history traits that are sensitive to population density
  - Density-dependent selection
- ***r*-selection** selects for life history traits that maximize reproduction
  - Density-independent selection

Population Change and Population Density

- In **density-independent** populations, birth rate and death rate do not change with population density
- In **density-dependent** populations, birth rates fall and death rates rise with population density

Mechanisms of Density-Dependent Population Regulation

- Density-dependent birth and death rates are an example of negative feedback that regulates population growth
- Density-dependent birth and death rates are affected by many factors, such as
  - Competition for resources
  - Territoriality
  - Disease
  - Predation
  - Toxic wastes
  - Intrinsic factors

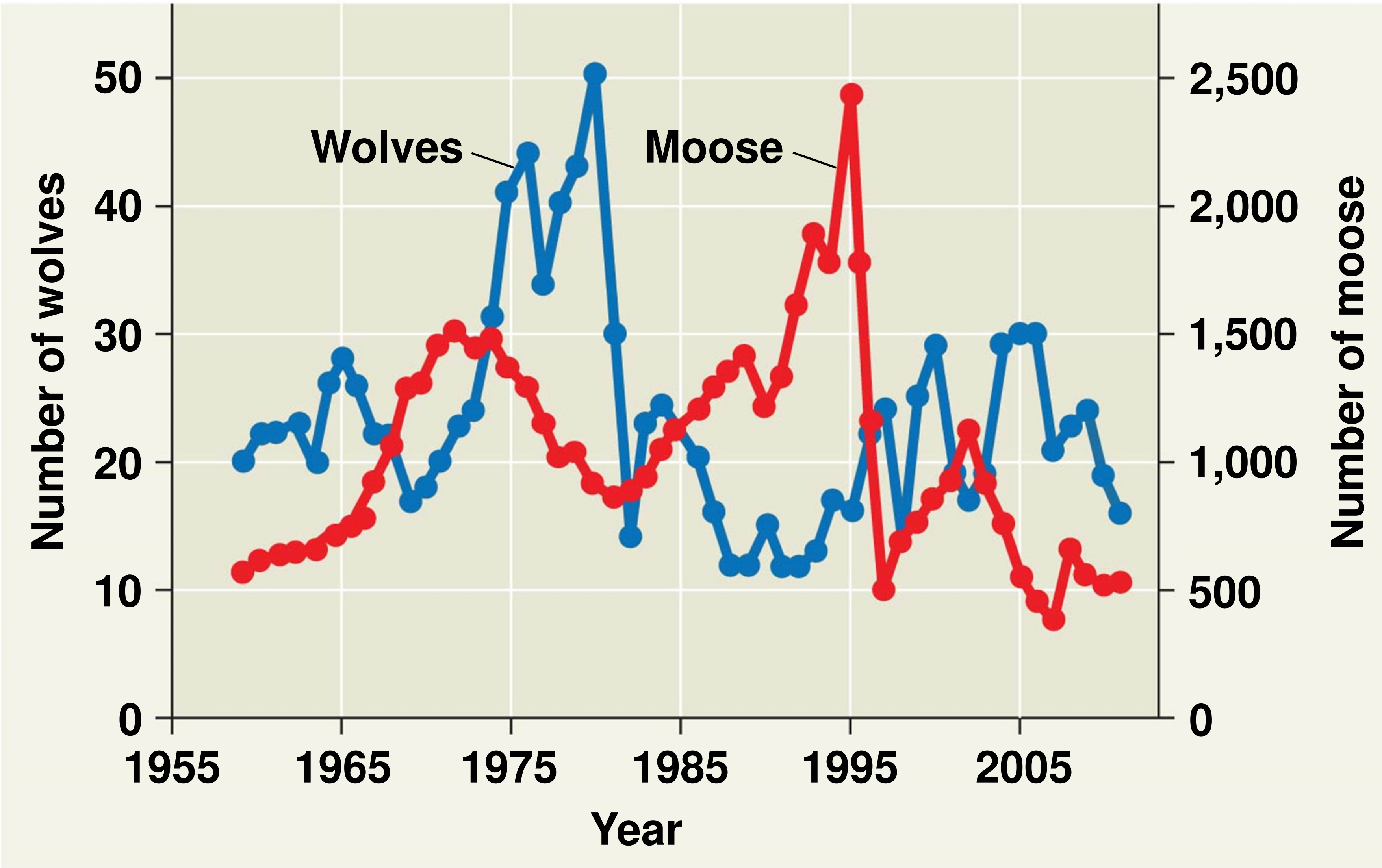
Population Dynamics

- The study of **population dynamics** focuses on the complex interactions between biotic and abiotic factors that cause variation in population size

Stability and Fluctuation

- Long-term population studies have challenged the hypothesis that populations of large mammals are relatively stable over time
- Both weather and predator population can affect population size over time
  - For example, the moose population on Isle Royale collapsed during a harsh winter and when wolf numbers peaked

Figure 40.24



Wolves
Moose
Number of wolves
Number of moose
50
40
30
20
10
0
2,500
2,000
1,500
1,000
500
0
1955
1965
1975
1985
1995
2005
Year

Immigration, Emigration, and Metapopulations

- **Metapopulations** are groups of populations linked by immigration and emigration
- Local populations within a metapopulation occupy patches of suitable habitat surrounded by unsuitable habitat
- Populations can be replaced in patches after extinction or established in new unoccupied habitats through migration

Figure 40.25